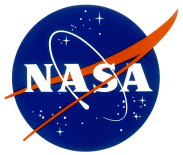

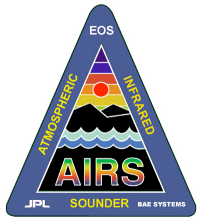


# Prelaunch and In-flight Radiometric Calibration of the Atmospheric Infrared Sounder (AIRS)

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# OVERVIEW OF RADIOMETRIC CALIBRATION IEEE PAPER

- **Presents radiometric transfer equation from first principles**
  - ***Includes gain and offset correction using OBC BB and SV***
  - ***Includes scan angle dependent polarization effects of scan mirror***
- **Equations are simple**
  - ***No crosstalk, stray light, fixed pattern noise, etc.***
- **Discusses and presents pre-flight calibration parameters**
  - ***OBC Emissivity and Temperature Offset Correction Terms***
  - ***Nonlinearity***
  - ***Polarization Effects***
- **Estimates Uncertainty**
  - ***Uses independent LABB tests to demonstrate residual errors***
  - ***Demonstration used L1B testbed***
  - ***Systematic (Bias) and Random (Noise) estimates presented***
- **Paper submitted to IEEE for review**

# RADIOMETRIC TRANSFER EQUATIONS

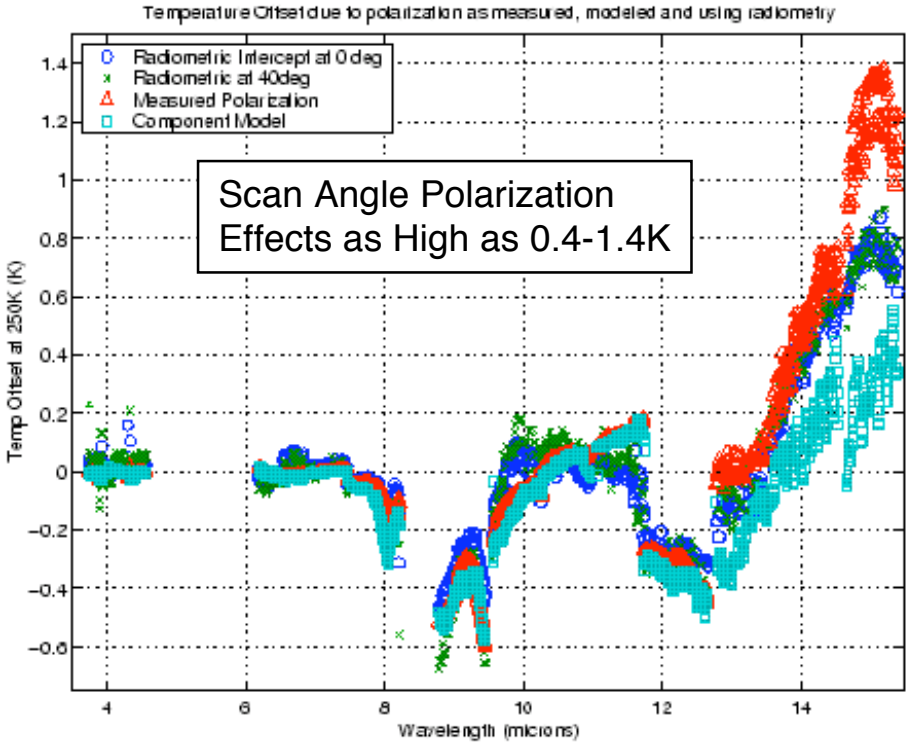
$$N_{sc,i,j} = \frac{a_o(\theta_j) + a_{1,i}(dn_{i,j} - dn_{sv,i}) + a_2(dn_{i,j} - dn_{sv,i})^2}{1 + p_r p_t \cos 2(\theta_j - \phi)}$$

$$a_o(\theta_j) = P_{sm} p_r p_t [\cos 2(\theta_j - \phi) + \cos 2\phi]$$

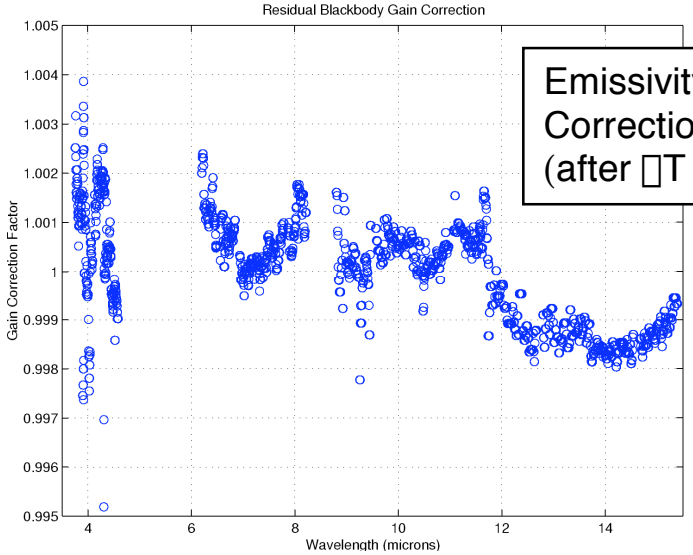
$$a_{1,i} = \frac{N_{OBC,i}(1 + p_r p_t \cos 2\phi) - a_o(\theta_{OBC}) - a_2(dn_{obc,i} - dn_{sv,i})^2}{(dn_{obc,i} - dn_{sv,i})}$$

$N_{sc,i,j}$ = Scene radiance of the $i^{th}$ scan and $j^{th}$ footprint ($mW/m^2$-sr-$cm^{-1}$)
*Psm* _ Plank radiation function evaluated at the temperature of the scan mirror.
$N_{OBC,i}$ = Radiance of the On-Board Calibrator ($mW/m^2$-sr-$cm^{-1}$)
i = Scan Index, j = Footprint Index (1 to 90), $\theta$ = Scan Angle. $\theta$ = 0 is nadir.
$dn_{i,j}$ = Raw Digital Number in the Earth View for the $i^{th}$ scan and $j^{th}$ footprint
$dn_{sv,i}$ = Space view counts offset. Algorithmic combination of 8 AIRS raw space view digital numbers.
$a_o$ = Radiometric offset. This is nonzero due to polarization and is scan angle dependent.
$a_{1,i}$ = Radiometric gain. $a_2$ = Nonlinearity Correction
$p_r p_t$ = Product of the polarization factor from the scan mirror and the spectrometer
$\phi$ = Phase of the polarization of the AIRS spectrometer

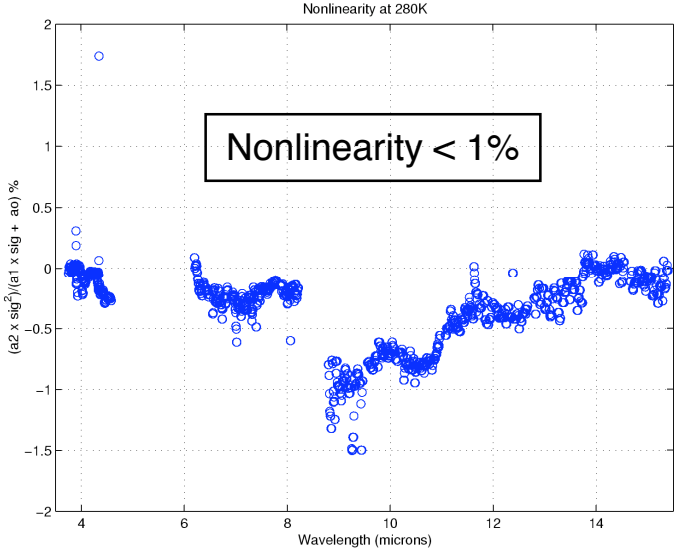
# PAPER HIGHLIGHTS
## PRE-FLIGHT CAL PARAMETERS




Scan Angle Polarization Effects as High as 0.4-1.4K



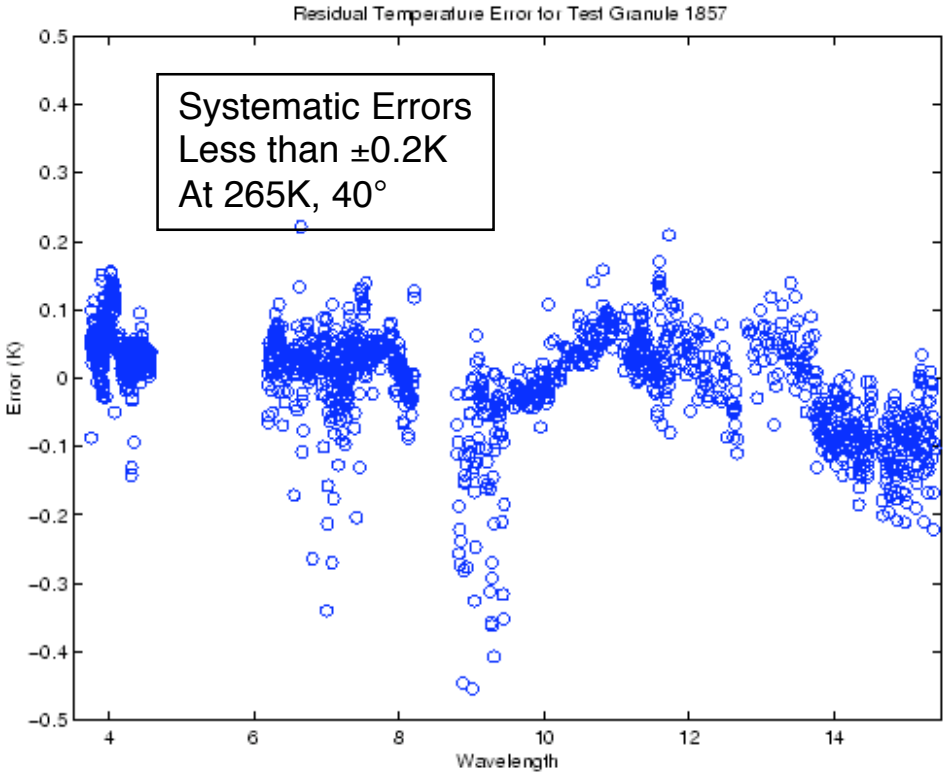

Emissivity (Gain) Correction < 0.2% (after ΔT = 0.3K)



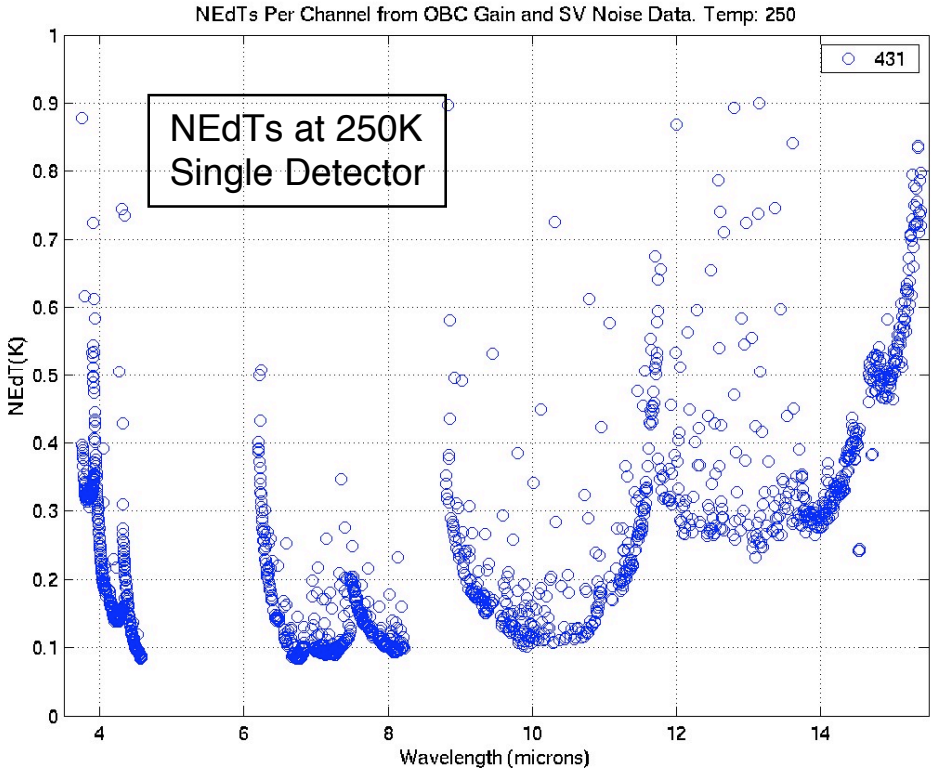

Nonlinearity < 1%

# PAPER HIGHLIGHTS
## RESIDUAL ERRORS

### Systematic Errors (Bias)




### Random Errors (Noise)



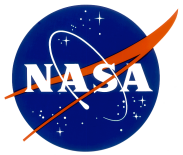
# AIRS CALIBRATION TEAM MEETING
## Agenda

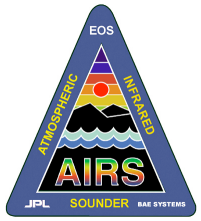
### Special Testing Status/Plans

- 12:00 PM: In-Flight Calibration Plan: T. Pagano
- 12:30 PM: Staffing and Processing Plans: T. Pagano
- 12:45 PM: C3:Channel Spectra Phase Test Results from TRW: M. Weiler
- 1:00 PM: C7:Space View Noise Test Results from TRW: M. Weiler
- 1:15 PM: L1A2MAT and Flight STS Interface: S. Licata

### PGE Verification and In-Flight QA Trending

- 1:30 PM: L1B PGE Radiometric Verification: T. Hearty
- 1:45 PM: In-Flight Calibration Flag Monitoring: T. Hearty
- 2:00 PM: L1B PGE Spectral Verification: S. Gaiser
- 2:15 PM: In-Flight Spectral QA Monitoring/Trending: S. Gaiser
- 2:30 PM: In-Flight Radiometric QA Monitoring/Trending: Broberg □
- 2:45 PM: Action Items
- 3:00 PM: Adjorn



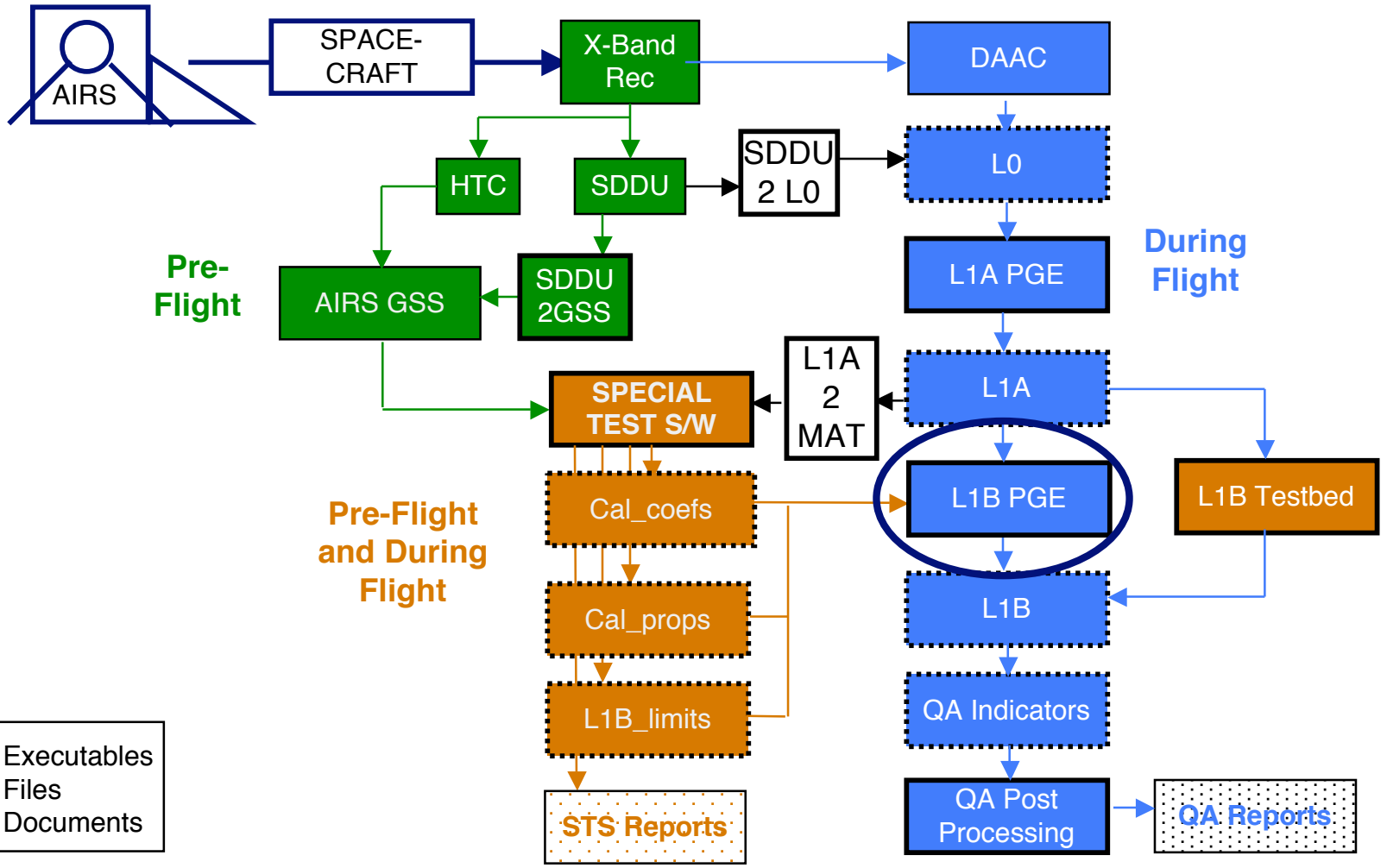



# IN-FLIGHT CALIBRATION OBJECTIVES AND PLANS

# AIRS INSTRUMENT CALIBRATION OBJECTIVES

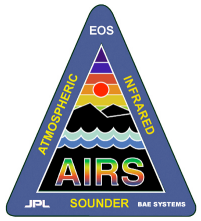
- **Configure the AIRS instrument for best performance**
  - ***Select A and B detector weights (gains)***
  - ***Align AMA for best radiometric and spectral performance***
  - ***Adjust temperature for best match of spectral centroids***
  - ***Select radiation circumvention thresholds to minimize effects of radiation on the noise performance***
- **Characterize the AIRS instrument in the on-orbit environment**
  - ***Detect gain changes and icing effects***
  - ***Characterize noise performance (amplitude and character)***
  - ***Characterize radiometric response and stray light***
  - ***Characterize the spectral response centroids and channeling***
- **Trend the performance over time and space**
  - ***Use L1B QA parameters to trend the spectral, spatial and radiometric performance of the instrument over time and space***

# TOOLS DEVELOPED PRE-FLIGHT WILL BE USED TO EVALUATE AND TREND



# SPECIAL TEST SEQUENCE PLANS (STS)

# SPECIAL TEST PLANS




- All special tests performed at TRW in Thermal Vacuum
- Test results analyzed and presented in TVAC Data Review (see http://airsteam.jpl.nasa.gov/calibration/Memos_Plans/TVAC_results.pdf)
- We will not get into test results today except for C3 (Spectral)
- All special test sequences expedited. This means L1A at JPL in less than 4 hours.
- All tests require quick turnaround of analysis in order to give feedback to the operations team for possible retest.
- Science Data Processing System Team must process to L1A ASAP
- Use L1A2MAT to convert to standard matlab format. Also use new tools for detecting valid scans and missing packets
- Analyst will be called as soon as L1A available to begin analysis

# TWELVE SPECIAL TEST OBTAIN KEY MEASUREMENTS

| Test ID | Name | Description | Measurement Obtained |
|---|---|---|---|
| AIRS-C1 | Normal Mode / Special Events | Establish normal DCR and Lamp operation.<br>Flag data for special events<br>Earth Scene targets of opportunity. | Focal Plane Model<br>Geolocation<br>SST Acquisitions |
| AIRS-C2 | Guard Test | Cycles through A, B and A/B Optimum Gains and acquires data. | Radiometric Gains<br>NEdT<br>Spectral FP Model (Parylene) |
| AIRS-C3 | Channel Spectra Phase | Heat and cool spectrometer by ±1K | Phase of Channel Spectra |
| AIRS-C4 | AMA Adjust | AMA is moved to the desired x (spatial) and y (spectral) position. | AB Balance<br>Spectral Adjust |
| AIRS-C5 | OBC Cool | Blackbody heater is turned off | IR Linearity |
| AIRS-C6 | Variable Integration Time | Integration time is varied on readout while scanning | Electronics Linearity |
| AIRS-C7 | Space View Noise | The scan mirror is stopped and parked at OBCs | Noise Behavior (Pops, FPN, etc)<br>Drift Characterization |
| AIRS-C8 | Radiation Circumvention | Same test as AIRS-C7 but with radiation circumvention turned on. | Threshold Levels |
| AIRS-C9 | Scan Profile | Slow part of scan rotated to OBCs | Stray Light<br>Calibrator Centration |
| AIRS-C10 | Lamp Operations | Each of the three lamps are exercised by user command. | VIS Gains, VIS Noise |
| AIRS-C11 | Warm Functional | Focal Plane Power is Cycled<br>Test Pattern Gain Table Loaded | FPA Functionality<br>Data Stream Verification |
| AIRS-C12 | Cold Functional | Same as AIRS-C11 except performed cold. | FPA Functionality |

☐ System Comprehensive Performance Tests (SCPT)

# STS GROUP 1, 2, 3, AND 4 TESTS USED TO CONFIGURE INSTRUMENT GAINS AND ALIGN AMA

| | | | | | |
|---|---|---|---|---|---|
| **Group 1:** | **Warm Functional** | | | | |
| C11 | Warm Functional | | Test Pattern | time_hist, test_pattern, emc | |
| C10 | VIS/NIR | All | C10 SNR on All Lamps | vis_snr | |
| | | | | | |
| **Group 2:** | **Normal Mode Science Data Acquisitions: 155K** | | | | |
| C1 | 3 Day Science Mode Trial | | Data Handling and Flow | image_sc, L1B PGE | Trial data set. Not calibrated |
| C2 | Guard | All | Gain Check | gain, gain_ratios | Perform daily, watch for icing |
| | | | | | |
| **Group 3:** | **Noise Acquisitions, 155K** | | | | |
| C7 | Space View Noise | A Space | A Noise in clean orbit | sv_nse, trend_params | One complete orbit required |
| | | B Space | B Noise in clean orbit | sv_nse, trend_params | for each |
| | | AB Space | AB Noise in clean orbit | sv_nse, trend_params | |
| | | A Space | A Noise in SAA | rad_circ, rc_time_hist | Time history of noise |
| | | B Space | B Noise in SAA | rad_circ, rc_time_hist | Determine tresholds |
| | | AB Space | AB Noise in SAA | sv_nse, trend_params | |
| | | | | | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | Perform daily, watch for icing |
| **Group 4:** | **AMA Adjust, 155K** | | | | |
| | | | | | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | |
| | | | X Position (AB Balance) | xdisp_offset | Determine x postion |
| | | | Y Position | gen_pary | Determine y position |
| | | | | | |
| C4 | AMA Adjust | All | Move of AMA | | |
| | | | | | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | |
| | | | X Position (AB Balance) | xdisp_offset | Determine x postion |
| | | | Y Position | gen_pary | Determine y position |
| ** Calculate new GNC tables using C7 and C2 data to date | | | | | |

# STS GROUP 5, 6, AND 7 TESTS CHARACTERIZE INSTRUMENT PERFORMANCE

| | | | | | |
|---|---|---|---|---|---|
| **Group 5: G&C Table Validation** | | | | | |
| C8 | Radiation | A Space | A Noise in clean orbit | sv_nse, trend_params | Verify noise hasn't changed |
| | Circumvention | B Space | B Noise in clean orbit | sv_nse, trend_params | Verify noise hasn't changed |
| | On | AB Space | AB Noise in clean orbit | sv_nse, trend_params | Validate AB Optimum |
| | | AB OBC | AB Noise in clean orbit | sv_nse, trend_params | Use for NEN vs Radiance |
| | | A Space | A Noise in SAA | rad_circ, rc_time_hist | Validate Thresholds |
| | | B Space | B Noise in SAA | rad_circ, rc_time_hist | Validate Thresholds |
| | | AB Space | AB Noise in SAA | sv_nse, trend_params | Validate Thresholds |
| | | | | | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | Perform Daily |
| **Group 6: Linearity and Stray Light** | | | | | |
| C5 | OBC Float | All | Linearity, OBC Cal | obc_float | |
| C6 | Variable Integration | All | Electronic Linearity | tint | |
| C9 | Scan Profile | All | Stray Light Check | scan_prof | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | Icing and gain stability |
| | | | | | |
| **Group 7: Channel Spectra Phase** | | | | | |
| C3 | Channel Phase Test | All | Determine Phase | | Wait 3 Days after this test |
| | | | of Channel Spectra | | and recheck AB Optimum |
| **Post Calibration Phase Tests** | | | | | |
| C2 | Guard | All | Gain Check | gain, gain_ratios | Perform Daily |
| | | | | | Next 30 Days |
| | Normal Mode | | | L1B PGE | L1B PGE Evaluations |

# SPECIAL TESTS PERFORMED IN FIRST 90 DAYS

| Calibration Sequence Timeline | | | |
|---|---|---|---|
| Day | Cal Sequence | Group | Notes |
| 15 | C11 | 1 | Warm Functional |
| 18 | C10 | 1 | Vis/NIR |
| 39 | C1, C2 | 2 | Daily Guard, 3 Days First Light |
| 44 | C2 | 2 | Choke point heater adjust based on spectral info |
| 49 | C7 | 3 | Space View Noise Tests |
| 50 | C2, C4 | 4 | AMA Adjust |
| 53 | C2, C8 | 5 | Radiation Circumvention Tests |
| 54 | C2, C4 | 4 | AMA Adjust |
| 56 | C2, C8 | 5 | G&C Table Validation |
| 59 | C2, C8 | 5 | G&C Table Validation |
| 62 | C2, C8 | 5 | G&C Table Validation |
| 63 | C2, C5, C6, C9 | 6 | Linearity and Stray Light Tests |
| 65 | C3 | 7 | Channel Spectra Phase Test |
| 67 | C2, C8 | 5 | G&C Table Validation |
| 72 | C3 | 7 | Channel Spectra Phase Test |
| 90 | | | AIRS Operational |

Note: G&C Table upload prior to G&C Table Validation

# DATA ANALYSIS AND STAFFING RESPONSIBILITIES

- **C1: Pagano, Broberg**
- **C2: Broberg, Licata, Gaiser**
- **C3: Weiler**
- **C4: Broberg, Gaiser**
- **C5: Hearty**
- **C6: Overoye**
- **C7: Weiler, Pagano**
- **C8: Weiler, Pagano**
- **C9: Overoye**
- **C10: Broberg, Hofstadter**
- **C11: Overoye**

Sun Workstation (eosws2)
Now online at GSFC
Also we have MacX

- **L0 to L1A: Manning, Ting**
- **L1A2MAT: Licata**
- **Telemetry: Broberg, Overoye**
- **L1B QA Trending**
  - ***Spectral: Gaiser***
  - ***Radiometric: Broberg***
  - ***Spatial: TBD***
  - ***Cal Flags: Hearty***
- **Operations Support at GSFC**
  - ***S. Gaiser***
  - ***T. Hearty*** Scheduled
  - ***S. Broberg***
  - ***T. Pagano***
  - ***M. Weiler*** Event Driven
  - ***K. Overoye***
  - ***S. Licata***